Mars Rover Image Data Prioritization for Increased Mission Science Return

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INTRODUCTION

Rover traverse distances are increasing at a faster rate than downlink capacity is increasing. As this trend continues, the quantity of data that can be returned to Earth per meter of traverse is reduced. The capacity of the rover to collect data, however, remains high. This circumstance leads to an opportunity to increase mission science return by carefully selecting the data with the highest science interest for downlink. We have developed an onboard science analysis technology for increasing science return from missions. Our technology evaluates the geologic data gathered by the rover, and prioritizes this data for transmission, so that the data with the highest science value is transmitted to Earth. Although our techniques are applicable to a wide range of data modalities, our initial emphasis has focused on image analysis, since images consume a large percentage of downlink bandwidth.

We have further focused our foundational work on rocks. Rocks are among the primary features populating the local Martian landscape. Characterization and understanding of rocks on the surface is a first step leading towards more complex in situ regional geological assessments by the rover. Data prioritization involves two processes: the identification of significant features in the data and the use of these features to assess the scientific value of the data. In our current application, we locate rocks in the image data and then extract properties of each rock, including albedo, visual texture and shape. These properties are then used to prioritize the rocks and thereby prioritize the images of the rocks.

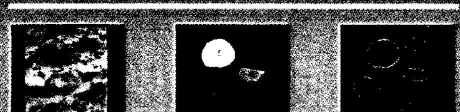
Three prioritization methods have been developed: identification of key target signatures, novelty detection, and sampling representative rocks. The use of these three methods ensures that three exploratory science objectives are met. First, objects known to be of very high interest, such as indicators of water, will be immediately recognized if encountered. Second, unexpected objects that may lead to key discoveries will be noted. It is, however, also important to have an understanding of the typical characteristics of the region. Our final prioritization method selects the most representative rocks for the downlink queue.

As NASA continues to increase the number of high data volume missions simultaneously operating, an onboard mechanism for the prioritization of data tagged for downlink that can increase the science content returned for a fixed bandwidth will be invaluable to scientists who will continue to compete for downlink time.

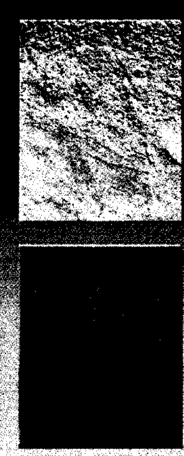
FEATURE EXTRACTION

Albedo

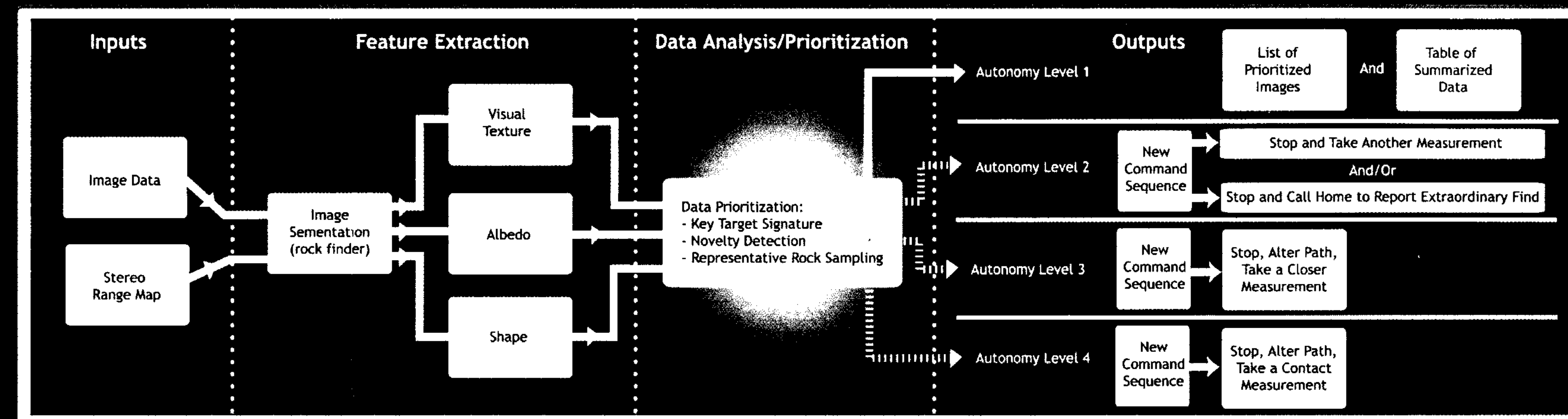
Shape



Texture



PROCESS DIAGRAM

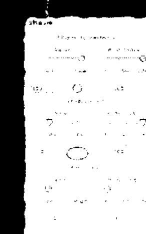


PRIORITIZATION TECHNIQUES

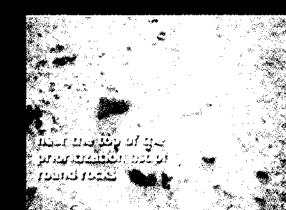
Key Target Signature

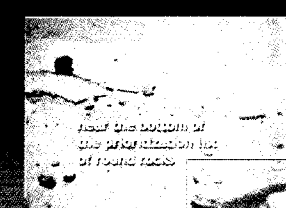
Scientists have studied areas extensively and have an idea of what they expect to see or encounter during an in situ mission. On a mission, the instruments have all been carefully selected to collect information that will provide valuable insight into the history or current conditions on the planet. Thus, when only limited data can be sent to Earth, it is very important to scientists that any data containing these signatures is among the data that is returned.

We have implemented a method for enabling scientists to efficiently and easily stipulate the value and importance to give each feature.

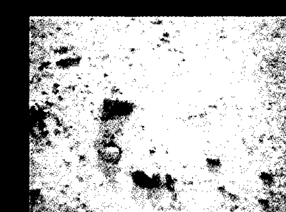


Key Target Signature Example - Shape: the search for round rocks





Novelty Detection



Sometimes the most interesting scientific discoveries occur when an object that appears out of place is identified. We have developed a method for detecting novel rocks that is based on a discrimination-based kernel one-class classifier. In this approach we treat a given set of rock data as the "positive class" and learn the discriminant boundary that encloses all that data in feature space. The rock data is essentially considered as a cloud of points in the feature space and the boundary of the cloud is learned.A rock being tested is considered novel if it's feature vector falls outside of the cloud boundary.

Representative Rock Sampling

One of objectives for rover traverse science is to gain an understanding of the region being traversed. As such, it is desirable to have information on rocks that are typical for a region, not just information on potentially very interesting unusual rocks, returned to Earth. A region is likely to be populated by several types of rocks with each type having a different abundance. A uniform sampling will be biased towards the dominant class of rock present and may result in smaller classes not being represented at all in the downlinked data.